

On an alleged Variability of the Sun's Diameter. By Dr. Auwers.*

(Abstract by W. T. Lynn, B.A.)

Lindenau found in reducing the observations of the Sun with the transit instrument at Seeberg, in the years 1808 and 1809, differences in the observed diameters which he thought could not be explained by errors of observation, especially as they seemed to be of a periodic nature. By a discussion of the meridional observations at Greenwich from 1750 to 1755, and from 1765 to 1786, he obtained an apparently complete confirmation of the reality of these variations and their periodical character, and was able satisfactorily to represent the observations by the hypothesis that the Sun was an ellipsoid rotating about its major axis; the compression, according to his calculation, amounting to something between $\frac{1}{279}$ and $\frac{1}{140}$.

This was communicated to the number of Zach's *Monatliche Correspondenz* for June 1809. In the following number of that periodical, Bessel remarked that the variations noticed in the Sun's apparent diameter at Greenwich could be explained by a periodical shifting of the wire-frame of the instrument in reference to the plane of the focus. Lindenau's investigation has not led to any further criticism; more accurate observations showing no deviation in the Sun's apparent disc from that of a circle, and his theory of a compression of the Sun's body was set aside as resulting from errors in the early observations.

Recently, however, Father Secchi, apparently unaware of this investigation of Lindenau, has conjectured that the effect of the active forces in the Sun, which are made known to us by the variable formations on its surface, may produce changes of volume in the masses of luminous gas, perhaps perceptible in accurate observations of the Sun's diameter. He, in consequence, caused his assistant at the Observatory of the Collegio Romano, P. Rosa, to make regular observations from July 1871, of the duration of the Sun's transit with the meridian-circle; the result of which appeared to confirm his suspicion of considerable variations in the Sun's diameter, and a close connection of this with the indications of the force forming the spots and protuberances. The variations in the apparent diameter were greatest when the activity of the forces was greatest; and (as Secchi asserted) these variations often exceeding 3" in amount were greater than, and could not be explained by, mere errors of observation. Their sometimes regular change also seemed to negative the latter idea; and at Secchi's instance, observations were afterwards made at the Palermo Observatory, which appeared to confirm the result obtained at Rome. They agreed in showing that "the greater diameter was observed at those times at which the number of the spots and protuberances was less."

* From the *Monatsbericht* of the Royal Academy of Sciences at Berlin for May 1873.

Secchi proceeded to compare the Roman observations (187 in number) with the heliographical latitudes of their end-points, which, during the year (1871 July to 1872 July) of observation, passed four times through the values from 0 to $\pm 26^\circ$. The curve formed from the observed values thus obtained appeared to him to be regular and confirmatory of each other in the four divisions they contained. He assumed therefore "a maximum of diameter between the equator and $\pm 6^\circ$ of heliographical latitude, its amount being $32'3''\cdot74$ and a minimum between $\pm 21^\circ$ and $\pm 23^\circ$ of latitude, the amount being $32'2''\cdot18$; the difference of the two being $1''\cdot56$, five times as great as the probable error of a single observation, whilst the value of the maximum was established by 31, and that of the minimum by 22, observations."

While Secchi does not attempt to claim these results, founded on only one year's observations, as final, he yet maintains them to be undeniable deductions from the observations made. Dr. Auwers, however, asserts that the foundations of his theory are so unreliable that the consequences deduced from it must be, for the present at any rate, absolutely rejected. In the first place, it is in opposition to all experience in the nature of errors of observation, to make the deviations of the separate observed transits from their mean the only measure of the possible errors. That greater fluctuations show themselves in the observed diameters than would correspond to these deviations can, up to a certain limit, only be regarded as a proof that the determination of the probable error of observation is incomplete; and that this limit has very probably not actually been exceeded by the fluctuations in the Roman observations is shown by an investigation,* by Herr Wagner, of Pulkowa, of a series of observations evidently surpassing those at Rome in their internal goodness. The observation of a transit of the Sun's limbs is affected to such an extent in this instance, by an element totally left out of account by Secchi,—namely, the state of the atmosphere and the quality of the image produced by its condition—that differences occur between means from repeated observations of the Sun's diameter made with the great transit instrument at Pulkowa, in good, and others in bad. states of air, of from $3''$ to $4''$, so that differences of from $5''$ to $6''$ between separate observations cannot certainly be regarded as anything surprising. The data for estimating the actual amount of influence produced in the Roman observations by the condition of the atmosphere are not furnished by Secchi, and it cannot, therefore, be decided how far this element is capable of explaining the observed fluctuations; but this circumstance is sufficient to overthrow the proof which he has deduced from those observations.

With regard to the alleged agreement between the Rome and Palermo observations, Dr. Auwers demurs to the fact; it appears,

* Published in the 1873 January part of the *Vierteljahrsschrift der Astronomischen Gesellschaft*.

indeed, that although both series assign a principal minimum on April 1872, yet a detailed examination shows that the general agreement of the deviations is scarcely more marked than the contrary. And as to the third proof of the reality of the variations observed at Rome, viz. their alleged connection with the visible fluctuations of intensity in the activity of the forces on the Sun, Dr. Auwers states that he can find no satisfactory data in the published observations for the somewhat arbitrary tabulation of Secchi, or the conclusions deduced from it. He proceeds to subject these conclusions generally to the test of a comparison with more comprehensive materials. This enquiry, he remarks, is not without an obvious importance in the question of the relative accuracy of the different methods of observation to be employed in the transit of *Venus*. For observations of which he has availed himself for this purpose, which have been made, but not yet published, at Greenwich, Neuchâtel, Oxford, Washington, Paris, Königsberg, Brussels—all taken during the same period of time as those at Rome—Dr. Auwers offers his thanks to Sir George Airy, Messrs. Becker, Main, Sands, Loewy, E. Luther, and Quetelet.

From the whole mass of observations, extending from July 1871 to July 1872, "it clearly results," says Dr. Auwers, "that Secchi's assertions concerning variations in the Sun's diameter are totally and entirely unfounded, and that the changes noticed by him are due to casual errors of observation." Of course, this conclusion is only meant to imply "that changes in the diameter, produced by such variations of activity in the superficial strata, as occur within one tenth of a solar-spot period (or generally any changes within a shorter period than this), are smaller than can be recognized within that period of time by meridional observations. The possibility remains of being hereafter able to perceive such changes, either by more delicate observations or by comparisons through longer intervals of time, such as whole sun-spot periods."

Dr. Auwers examined some heliometer observations of the Sun; but the number available is not great, and no conclusion of certainty can be derived from them. He has also put together a long series of Greenwich observations by Bradley and Maskelyne and their assistants; and some shorter ones by Bessel at Königsberg, and by W. Struve at Dorpat, with the view of ascertaining whether there is any observable connection between the Sun's apparent diameter and the state of the solar-spot period; but he does not find it possible to trace any such connection. Finally, he has compared the values of the Sun's diameter given in the last twenty years in the Greenwich Introductions (from 1851 to 1870) deduced from the Transit-Circle observations, which again show, when compared with Wolf's relative number of the solar-spot condition, "that in the fluctuations of the observed values, both for the horizontal and vertical diameters, and the difference between the two, no dependence upon the variations of the degree of activity, and, therefore, no indication whatever of the reality of these fluctuations can be perceived."